Soldier Performance and Strenuous Road Marching: Influence of Load Mass and Load Distribution

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Fifteen male soldiers performed six maximal-effort, 20-km road marches. They carried load masses of 34, 48, and 61 kg, using a standard military backpack with frame or an experimental doublepack. March times decreased as mass increased and were faster with the standard pack than with the doublepack. The doublepack resulted in less low back discomfort and a lower incidence of blisters at the highest load, but also resulted in more discomfort in the neck and hips. Neither load mass nor pack type affected soldiers' marksmanship ability, grenade throw accuracy, or cognitive ability. The maximal-effort march itself affected the marksmanship task by increasing the post-march vertical shot group dispersion. The concept of distributing the load mass more evenly around the center of mass of the body has both positive and negative aspects and warrants further investigation.

Introduction

U.S. Army doctrine recommends that soldiers carry maximum combat loads of 22 kg and maximum approach march loads of 33 kg.[1] These loads are based on historical experience[2] and energy-cost studies suggesting that loads in this range are carried most economically per unit of distance.[3] However, soldiers typically carry loads far exceeding these recommendations. In exercises conducted at the Joint Readiness Training Center (Fort Chaffee, Arkansas), soldiers toted average loads of 40 kg and maximal loads of 69 kg.[4]

Many factors influence a soldier's load carriage ability, including load mass, march speed, type of terrain,[5,6] load distribution,[7] and the medical condition of the soldier.[8] Some of these factors have been studied, usually in relation to energy cost; however, soldier performance is usually of more interest to the commander. A commander's typical concerns include the amount of time required for soldiers to complete a march and soldiers' ability to execute mission-related tasks at the end of the march. Information of this type would assist commanders in making informed decisions for specific military operations.

This study was a multidisciplinary effort with three major objectives. The first was to determine the effects of load mass and load distribution on maximal-effort road march time and heart rate. The second objective was to examine the influence of load mass, load distribution, and the march itself on cognitive ability, performance of typical soldiering tasks, and subjective feelings of pain and discomfort. A final objective was to examine the influence of load mass and load distribution on foot blisters, one of the most common road march injuries.[8]

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Methods

Subjects

Subjects were 15 male Special Operations Forces soldiers who were healthy as determined by physical examination, blood tests, and urinalysis. Soldiers were briefed about the purposes and risks of the study and all volunteered for the investigation. They provided their written informed consent in accordance with Army Regulation 70-25. The study was approved by the institutional human use review boards of all organizations.

Procedures

There were two phases to the study, a pre-test phase and the experimental road marches. The purpose of the pre-test phase was to obtain soldiers' physical characteristics and familiarize them with the tests they would perform before and after the road marches.

Pre-Test Phase

The soldiers' stature and weight were measured with an anthropometer (GPM) and calibrated digital scale (SECA), respectively. Body fat was estimated from stature and the circumferences using a standard Army equation.[9] Subjects performed a 2-mile run for time on a flat (no grade) course.

The marksmanship task was conducted on an indoor rifle range. Soldiers fired M-16 rifles from a prone, unsupported position. Thirty rounds were fired at three separate bull's-eye targets (10 rounds per target). The soldiers had 1 minute to fire 10 rounds at the first target, followed by 2 minutes of rest before firing the next 10 rounds. Rifles were not individually zeroed. Soldiers were told to obtain a good "sight picture" before firing and that a higher score would be obtained for a "tight shot group." To examine the influence of heart rate on marksmanship, Uniq model 8799 heart-rate monitors were used to obtain soldiers' heart rates immediately before they fired at each target. Two practice sessions were conducted over 2 days before the first experimental road march.

A grenade throw for accuracy involved throwing "dummy" hand grenades at a bull's-eye target on the ground. The centroid of the target was 35 m from the throw line. Distance was measured from where the grenade landed to the centroid of the target. The mean of five distances served as the performance score. Before the experimental road marches each soldier was allotted 20 practice throws over a 2-day period.

Subjects performed the synthetic work environment (Syn Work) task to evaluate cognitive ability.[10] This task involved four separate tasks presented simultaneously in quadrants of a computer screen. The soldier determined how to budget his time among the exercises. Exercises include a memory task, a mathematical task, a visual monitoring exercise, and an auditory monitoring activity. For the latter, two tones were presented periodically (1,046 and 1,319 Hz) and the soldier was required to respond to the higher frequency. Soldiers practiced the Syn Work task during six 20-minute sessions.

Road March Phase

There were six experimental marches, all on the same 20-km course. In separate marches, soldiers carried 34, 48, or 61 kg using either (1) the backpack portion of the large all-purpose lightweight individual carrying equipment (ALICE) pack or (2) an experimental doublepack, which evenly distributed the load between the front and back of the body. Loads were the total mass of equipment and clothing on the soldier's body. All soldiers performed in all six conditions, and the order of testing was such that each soldier was equally likely to have a particular pack and load combination on a given day. There were 3 to 4 days of rest between marches. Before the first experimental march, soldiers performed a self-paced practice march (34 kg, 20 km) to allow them to become familiar with the course and recover from possible muscle soreness.[11]

The 20-km course was essentially flat with about 8 km on dirt roads and 12 km on paved roads. All soldiers started the march at the same time and were instructed to complete the march as rapidly as possible. They were directed to rest only at designated 4-km checkpoints. At these checkpoints, a technician recorded the arrival time and the amount of time the soldier spent at the check point (rest time).

The experimental doublepack is shown in Figure 1. The rear portion of the pack was a slightly modified medium ALICE pack with frame. The front portion of the pack was a cordura bag with two aluminum vertical staves on the back side. The staves were designed to reduce the load on the shoulders and place it on the hip belt. The hip belt was 4 inches wide, ran around the entire pack, and was padded with half-inch foam. Buckles and adjustment straps were positioned on both sides of the belt. Load mass was distributed so that 50% was in the front portion and 50% in the back portion.

Soldiers were instrumented with Uniq model 8799 heart-rate monitors before each march. This device consisted of an electrode strap the subject wore on his chest and a watch worn on the wrist. The electrode strap contained a transmitter that conveyed heart-rate signals to the watch, where they were stored for later downloading to a computer.

Before and after each march, soldiers completed the marksmanship, grenade throw, and Syn Work tasks. Selected times to begin each task after the march were 10, 25, and 35 minutes for the marksmanship, grenade throw, and Syn Work tasks, respectively. Technicians recorded when the soldier arrived and departed the test areas.

At the conclusion of all performance testing, soldiers completed the rating of pain, soreness, and discomfort (RPSD) questionnaire[4] and had their feet examined for blisters. The RPSD questionnaire required soldiers to rate pain, soreness, and discomfort in 22 body segments on a 6-point scale using a two-dimensional reference figure. To determine foot blisters, soldiers removed their boots and a technician visually examined both feet.

Fig. 1. Experimental doublepack. The rear portion of the double pack (alone) is the ALICE pack.

Data Analysis

Road march times were analyzed with a 2 × 3 × 5 (packs × load mass × 4-km distance intervals) repeated-measures analysis of variance (ANOVA). Heart rates were averaged over 4-km distance intervals and analyzed in the same way. Grenade throw, Syn Work data, and the RPSD were analyzed using a 2 × 3 × 2 (packs × load mass × pre/post-march) repeated-measures ANOVA. When significant effects were found in multi-level ANOVA, a one-way ANOVA and Tukey test were used to isolate differences between conditions. Foot blister data were analyzed with the McNemar test.

For the marksmanship task, each target was scored using an *XY* coordinate (horizontal-vertical) with the 00 coordinate at the bottom left-hand corner. The distance of each shot from the horizontal axis and the distance of each shot from the vertical axis was measured. Three values were obtained for each target: (1) the standard deviation of the 10 shots in the horizontal axis (S_h); (2) the standard deviation of the 10 shots in the vertical axis (S_v); and (3) the radial standard deviation (S_r).[12] Each of these measures was analyzed using a 2 × 3 × 2 × 3 ANOVA (packs × load mass × pre/post-march × target).

Results

Subjects' average (±SD) age, height, weight, body fat, and 2-mile run times were 29.7 ± 4.3 years, 175.8 ± 5.5 cm, 87.8 ± 10.3 kg, 21.0 ± 3.6%, and 13.7 ± 1.2 min, respectively.

Road March Times and Heart Rate

Table I shows descriptive statistics about cumulative march times at each checkpoint. Soldiers completed the march more

TABLE I

DESCRIPTIVE STATISTICS OF CUMULATIVE ROAD MARCH TIMES (MINUTES)

Pack and Load Mass[a]		Distance				
		4 km	8 km	12 km	16 km	20 km
A34	Mean	33	65	99	135	171
	SD	5	10	16	23	31
A48	Mean	40	80	124	171	216
	SD	7	11	18	28	34
A61	Mean	44	91	148	199	253
	SD	4	10	32	19	26
D34	Mean	35	70	105	151	181
	SD	5	9	14	33	30
D48	Mean	39	82	126	175	225
	SD	4	9	14	22	29
D61	Mean	48	101	156	216	276
	SD	8	15	22	31	45

[a]A = ALICE pack, D = doublepack; numbers following letters are the loads (kg).

rapidly with the ALICE pack than with the doublepack ($p < 0.001$). Soldiers also completed the march more rapidly with lighter load masses; post-hoc tests indicated differences among all three load masses ($p < 0.001$). A significant pack × distance interaction ($p < 0.001$) indicated that at each checkpoint, time became progressively longer with the doublepack. A significant load mass × distance interaction ($p < 0.001$) illustrated that at each checkpoint, the time differences among the loads became progressively greater. There was no significant pack × load mass interaction ($p = 0.24$).

Average(±SD) rest times for the 34-, 48-, and 61-kg conditions were 2.1 ± 3.2 min, 11.5 ± 13.8 min, and 15.7 ± 11.2 min, respectively, for the ALICE pack; these values were 3.3 ± 4.0 min, 10.1 ± 11.4 min, and 22.0 ± 11.2 min, respectively, for the doublepack.

Table II shows descriptive statistics of heart rates. Soldiers had a lower heart rate while marching with the doublepack than with the ALICE pack ($p < 0.001$). Load mass also influenced heart rate ($p < 0.001$), with higher heart rates when soldiers carried the 34-kg mass compared to the other two masses ($p < 0.01$); there was no difference between the 48- and 61-kg masses. Heart rate changed little over the distance intervals ($p = 0.15$), and there were no significant pack × load mass ($p = 0.50$), pack × distance ($p = 0.88$), or load mass × distance ($p = 0.31$) interactions.

TABLE II

DESCRIPTIVE STATISTICS OF HEART RATES (BEATS/MINUTE) DURING THE ROAD MARCHES

Pack and Load Mass[a]		Distance Interval				
		0–4 km	4–8 km	8–12 km	12–16 km	16–20 km
A34	Mean	155	160	157	155	154
	SD	13	13	16	17	20
A48	Mean	142	145	142	142	143
	SD	17	19	17	16	19
A61	Mean	143	141	140	139	140
	SD	14	16	10	10	12
D34	Mean	145	151	149	150	150
	SD	14	17	16	15	18
D48	Mean	142	141	137	136	136
	SD	14	14	13	14	14
D61	Mean	140	138	135	137	141
	SD	15	15	16	13	13

[a]A = ALICE pack, D = doublepack; numbers following letters are the loads (kg).

Pre- and Post-March Testing

The mean (±SD) times from the end of the march to the beginning the marksmanship, grenade throw, and Syn Work tasks were 11.9 ± 2.0 min, 25.0 ± 4.4 min, and 39.9 ± 9.1 min, respectively. Thus, post-march events were conducted very close to the desired times.

Marksmanship

The first three columns of Table III show ANOVA probabilities for the three marksmanship variables. There were significant main effects for the march and targets for both S_v and S_r. The march × target interaction indicated that soldiers exhibited more variability on the vertical axis (S_v) after the march, but only when firing at the first target (illustrated in Fig. 2). Since S_r has a vertical component, this measure demonstrated a pattern identical to S_v.

Pre-firing heart-rate ANOVA probabilities are shown in the last column of Table III. Table IV displays descriptive statistics. Subjects had higher pre-firing heart rates after carrying the ALICE pack than after carrying the doublepack. Pre-firing heart rates were higher after soldiers carried the 34-kg mass compared to the 48- or 61-kg masses, but there were no differences between the latter two load masses. Pre-firing heart rates were elevated after the march compared to values before the march. There were differences among the three targets, with post-hoc tests indicating higher heart rates before firing at the first target ($p < 0.01$) but no heart-rate difference before firing at targets two and three. The load mass × march interaction indicated that the elevation in pre-firing heart rate after the march was greater after soldiers carried the 34-kg mass than when they carried the other two loads.

TABLE III

ANALYSIS OF VARIANCE PROBABILITIES FOR MARKSMANSHIP MEASURES AND PRE-FIRING HEART RATES

	S_h	S_v	S_r	HR
Pack (P)	0.10	0.19	0.12	0.03
Load mass (L)	0.26	0.11	0.10	0.04
Pre-post March (M)	0.81	0.00	0.02	0.00
Target (T)	0.56	0.00	0.00	0.00
P × L	0.07	0.52	0.18	0.78
P × M	0.88	0.22	0.32	0.62
P × T	0.71	0.53	0.69	0.99
L × M	0.62	0.84	0.74	0.01
L × T	0.22	0.35	0.22	0.21
M × T	0.26	0.00	0.01	0.30
P × L × M	0.42	0.32	0.18	0.38
P × L × T	0.30	0.70	0.62	0.99
P × M × T	0.64	0.74	0.80	0.84
L × M × T	0.96	0.83	0.97	0.12

S_h, S_v, and S_r = horizontal, vertical, and radial standard deviations, respectively; HR = heart rate.

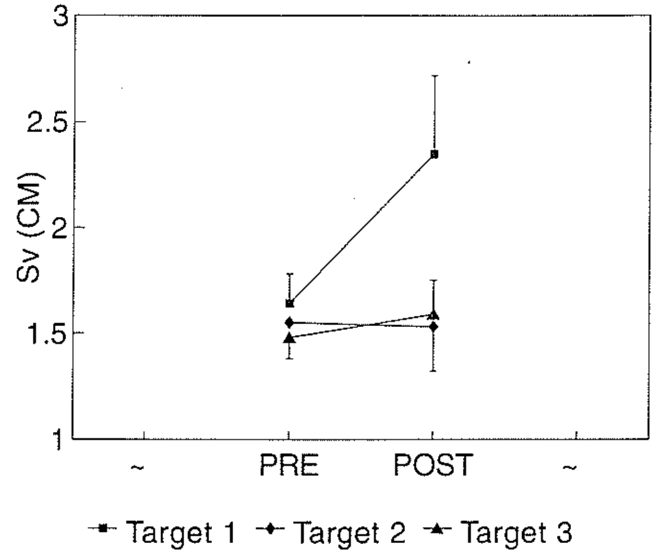

Fig. 2. March × target interaction for vertical standard deviation on the marksmanship task. Vertical bars are standard error.

TABLE IV

PRE-FIRING HEART RATES (BEATS PER MINUTE) DURING MARKSMANSHIP TASK

Pack and Load Mass[a]		Pre-March			Post-March		
		T1[b]	T2	T3	T1	T2	T3
A34	Mean	98	95	92	109	106	104
	SD	12	11	16	14	13	16
A48	Mean	97	94	97	106	103	102
	SD	13	13	14	12	13	12
A61	Mean	99	96	95	104	102	99
	SD	11	10	10	15	12	12
D34	Mean	97	94	91	107	105	103
	SD	11	10	11	14	13	14
D48	Mean	97	95	97	103	99	97
	SD	11	14	14	11	11	10
D61	Mean	95	91	92	102	100	97
	SD	14	12	12	15	13	12

[a]A = ALICE pack, D = doublepack; numbers after letters refer to load masses (kg).
[b]T = target; number indicates target number.

To examine the influence of heart rate on marksmanship, Pearson product moment correlations were performed between the heart-rate values and the three marksmanship scores. There appeared to be little relationship: correlations clustered around zero with a range of −0.33 to 0.46. The S_v was also adjusted for the pre-firing heart rate using analysis of covariance. The significant pre- vs. post-march change in S_v remained [1.63 cm vs. 2.34 cm, $F(1,13) = 5.53$, $p = 0.04$].

Grenade Throw

Descriptive statistics of the grenade throw data are shown in Table V. Analysis of grenade throw scores showed no significant main effects or interactions ($p \geq 0.16$).

Syn Work Task

Because of computer problems there were only 12 subjects with complete data on the Syn Work task. Despite the familiarization sessions, the total score continued to increase over trials during the marches. This was primarily because of an unexpected improvement in the arithmetic task. Thus, an additional analysis of the total score was performed without the arithmetic task.

TABLE V

DESCRIPTIVE STATISTICS FOR GRENADE THROW ACCURACY (DISTANCE FROM CENTROID IN CM)

		Pack and Load Mass Combination[a]					
		A34	A48	A61	D34	D48	D61
Pre-march	Mean	99	126	136	124	110	107
	SD	42	37	49	40	22	43
Post-march	Mean	137	119	112	124	110	115
	SD	63	50	42	36	26	24

[a]A = ALICE pack, D = doublepack; numbers after letters refer to load mass (kg).

None of the six Syn Work variables demonstrated significant main effects for pack ($p > 0.14$), load mass ($p > 0.30$), or pre/post-march ($p > 0.11$). There were three significant interactions. The auditory monitoring task displayed a significant load × march interaction ($p = 0.03$), indicating a decrement in performance after the march with the 34-kg load that was not seen with the other two loads. The math task demonstrated a significant pack × pre/post-march interaction ($p = 0.01$), indicating that there was a slight improvement in post-march performance with the ALICE pack and a slight decrement in post-march performance with the doublepack. The total score also demonstrated a significant pack × pre/post-march interaction ($p = 0.04$), with improved post-march performance with the ALICE pack and little post-march performance change with the doublepack.

Rating of Pain, Soreness, and Discomfort

Table VI shows the ANOVA probabilities for each of the 22 body segments evaluated in the RPSD questionnaire. The doublepack resulted in a higher RPSD in the anterior neck, posterior neck, and abdomen and hips regions; the ALICE pack had a higher RPSD in the calves. When significant main effects of the load mass were reported, soldiers reported a higher RPSD for the 61-kg mass than for either the 48- or 34-kg masses; there was little difference between the two latter masses. When significant march effects were found, soldiers reported a higher RPSD after the march.

The pack × load mass interaction for the low back area indicated that soldiers reported lower RPSD with the doublepack when carrying the 61-kg mass. The pack × march interaction indicated that soldiers reported a greater post-march RPSD for the doublepack in the anterior neck, posterior neck, anterior shoulders, anterior hands, posterior hands, abdomen and hips, anterior thighs, and buttocks.

The load mass × march interaction indicated that soldiers reported greater post-march PSD for the 61-kg mass than for the other two masses in the anterior shoulders, abdomen and hips, posterior neck, posterior shoulders, and calves. For lower back and buttocks, there were significant post-march differences among all loads with the 61-kg mass, resulting in the highest PSD. För the heels both the 61- and 48-kg masses resulted in higher post-march PSD than did the 34-kg mass.

TABLE VI

ANALYSIS OF VARIANCE PROBABILITIES FOR PAIN, SORENESS, AND DISCOMFORT QUESTIONNAIRE

	Neck	Shoulder	Upper Arm	Lower Arm	Hands	Upper Chest	Lower Chest	Abdomen, Hips	Thigh	Lower Leg	Feet
Anterior body											
Pack (P)	0.03	0.29	0.42	0.16	0.77	0.77	0.36	0.02	0.13	0.53	0.26
Load mass (L)	0.05	0.00	0.41	0.18	0.07	0.50	0.01	0.00	0.22	0.41	0.17
March (M)	0.01	0.00	0.17	0.55	0.84	0.08	0.25	0.00	0.03	0.16	0.00
P × L	0.99	0.72	0.84	0.46	0.43	0.41	0.33	0.09	0.99	0.91	0.75
P × M	0.04	0.04	0.75	0.16	0.03	0.86	0.83	0.02	0.02	0.93	0.27
L × M	0.45	0.00	0.91	0.58	0.89	0.97	0.45	0.01	0.26	0.95	0.20
	Neck	Shoulder	Upper Arm	Lower Arm	Hands	Upper Back	Lower Back	Buttocks	Thigh	Calf	Heel
Posterior body											
Pack (P)	0.03	0.99	0.08	0.99	0.77	0.79	0.30	0.22	0.13	0.05	0.69
Load mass (L)	0.02	0.00	0.18	0.71	0.07	0.07	0.05	0.00	0.66	0.87	0.14
March (M)	0.00	0.00	0.72	0.30	0.84	0.01	0.00	0.00	0.01	0.00	0.00
P × L	0.66	0.46	0.62	0.27	0.43	0.70	0.03	0.84	0.52	0.09	0.49
P × M	0.02	0.47	0.58	0.10	0.03	0.99	0.66	0.06	0.83	0.33	0.17
L × M	0.02	0.00	0.79	0.71	0.79	0.07	0.04	0.00	0.50	0.03	0.04

Foot Blisters

Blister incidence is shown in Table VII. The 61-kg load with the ALICE pack resulted in a greater blister incidence than any other pack and load combination ($p < 0.05$). There were no differences among other conditions ($p > 0.05$).

Discussion

As loads increased, march times increased in consonance with studies[3,13] over much shorter distances (5 and 6.4 km). However, contrary to past treadmill studies, heart rates did not change significantly during the march. When subjects walked with heavy loads on a treadmill and speed was held constant, oxygen uptake and heart rate increased over time.[6] In the present study and a previous one,[4] soldiers maintained a constant heart rate while their march speed declined slightly over the course of the march. These data suggest that soldiers tend to maintain a relatively constant exercise intensity during a maximal-effort road march.

Faster march times with the ALICE pack may be attributable to better familiarity with the ALICE pack as well as design problems with the experimental doublepack. In interviews conducted after the marches, soldiers generally preferred the ALICE pack to the doublepack. Soldiers commented that the ALICE pack was well balanced and stable on the body and that it was easy to adjust. With the experimental doublepack, soldiers noted that the waist belt frequently loosened and that the front portion oscillated as the soldier walked.

TABLE VII

BLISTER INCIDENCE (NUMBER OF SOLDIERS) AFTER CARRYING VARIOUS PACK-LOAD COMBINATIONS

	Pack and Load Mass Combination[a]					
	A34	A48	A61	D34	D48	D61
Blisters	6	7	12	8	6	6
No blisters	9	8	3	7	9	9

[a]A = ALICE pack, D = doublepack; numbers after letters are load masses (kg).

When soldiers carried the experimental doublepack, they reported greater post-march discomfort in the neck and abdomen-hip regions; however, they reported less discomfort in the low back region when carrying the 61-kg load with the doublepack. Low back problems are a leading cause of inability to complete strenuous road marches.[8] Biomechanical studies show that subjects assume a more upright walking posture with the doublepack (compared to a backpack) and this effect is greatest with heavier loads.[7] Thus, it is possible that the doublepack may help reduce postural strain while road marching.

At the highest load mass, the ALICE pack resulted in a higher blister incidence than the doublepack did. Blisters appear to be caused by repeated shearing forces acting on the skin (the movement of the foot in the boot). These shearing forces generate mechanical fatigue in epidermal cells, leading to the loss of cell integrity and the development of blisters.[14] Compared to doublepacks, backpacks produce greater maximal breaking force in the anteroposterior direction; similarly, heavy loads increase breaking forces compared to light loads.[7] In the present study, walking with the ALICE pack may have produced higher maximal breaking forces, resulting in more movement of the foot inside the boot, increasing shear forces and blister formation. The doublepack may have generated lower shear forces, reducing the probability of blister formation.

On the marksmanship task, an increase in vertical shot dispersion (S_v) was found following the road marches. This effect was brief since it occurred only when subjects fired on the first target. Nonetheless, it supports[15] and expands[16] previous findings of decreased marksmanship accuracy following maximal-effort marches. Post-exercise factors that cause small movements of the rifle may explain this decrease in performance. These factors include fatigue of the muscle groups that vertically stabilize the rifle,[15] elevated post-exercise respiration, fatigue-induced tremors, or elevated post-exercise heart rate.[16]

In the present study, post-exercise heart-rate elevations did not appear to be related to marksmanship performance. Heart rates were higher at the end of the march than at the start but correlations between pre-firing heart rates and S_v were low. Also, when S_v was adjusted for the pre-firing heart rate, the post-march increase in the vertical shot group dispersion remained. Finally, pre-firing heart rates were highest following marches with the 34-kg loads but the post-march increase in S_v was no greater than with the other loads. Note that the elevations in post-exercise heart rate were small (5–10 beats/minute). Also, the prone, unsupported firing position employed in this study may have minimized the influence of heart rate on marksmanship since the elbows were braced on the ground.

The grenade throw for accuracy was not affected by the march. It was previously demonstrated that there was a decrement in the maximal distance that a grenade could be thrown following a strenuous march.[16] It was hypothesized that this could be associated with a nerve entrapment syndrome[17] or pain in the muscle groups used for this task.[16] Although these factors may reduce maximal throwing distance, the ability to accurately throw a grenade at a nearby target (35 m) does not appear to be affected.

The auditory monitoring performance of the Syn Work task declined after marches with the 34-kg load mass but not with the other load masses. The reasons for this are not clear. Soldiers completed the march most rapidly with the 34-kg mass, and their energy expenditure rates (indicated by heart rate) were highest with this load mass. However, a study that examined the effects of moderate exercise on auditory vigilance showed little effect.[18] Studies examining the effects of short-term exercise on the threshold for hearing have demonstrated temporary threshold increases in the 1,000-Hz range[19] but not at higher frequencies.[20] The significant pack × march interactions for the mathematical task and the total Syn Work score are also difficult to interpret because stable baseline performance was not achieved on the mathematical task.

In conclusion, this study indicates that maximal-effort march times will decrease as the load mass increases, but the load mass has minimal influences on the post-march performance of some military tasks. The maximal-effort march itself (regardless of load mass or pack type) decreases marksmanship accuracy by increasing shot dispersion in the vertical axis. The concept of moving some of the load to the front of the body (the doublepack) has both positive and negative aspects but certainly deserves further investigation. Also, studies distributing the load in proportions other than 50% front and 50% back could provide additional insight.

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